

Effect of Fluoridated Public Water Supplies On Dental Caries Prevalence

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SUBSEQUENT to the epidemiological and experimental findings that the use of fluoride waters reduced the prevalence of dental caries, a number of studies were undertaken to evaluate the effects of adjusting the fluoride levels of public water supplies to an optimum concentration, about 1 ppm of fluoride (F). Preliminary and annual reports from these study areas have appeared in the literature from time to time during the past 5 or 6 years (1-9). Essentially, the findings of all these studies are in accord although each has its individual characteristics from a procedural standpoint.

The present paper reports in more detail than a preliminary report (1) the methodology and results of one of these studies, namely, the Grand Rapids-Muskegon study, and includes the results obtained after 6½ years of fluoridation of the Grand Rapids water supply.

Selection of Study Area

Because much of the background data regarding the effects of fluoride waters on dental

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caries was obtained in the north central part of the United States, this general area was selected for the fluoridation project. The choice was further influenced by the fact that (a) a considerable amount of data had been obtained on children who had used domestic water supplies for which Lake Michigan was the source, and (b) all evidence suggested that this general area had a high dental caries experience rate (10). Following a careful survey of a number of communities in this area, and with due consideration of the numerous details which influence a project of this sort, the city of Grand Rapids, Mich., was selected for the primary study area. The city of Muskegon, Mich., which has the same source of water and similar treatment procedures as Grand Rapids, was chosen as a control area. To establish what might be termed an "expectancy curve" for this study, a natural fluoride area, the city of Aurora, Ill., was selected. The Aurora water supply contains 1.2 ppm F and has a reliable history of constancy back to 1895 (11).

Base-Line Examinations

Dental examinations were started in Grand Rapids in September 1944. Four trained dental officers performed the examinations in selected schoolrooms, using mouth mirrors and explorers, and standard type examining lights. The examining equipment throughout the study has been a double-end SSW No. 3 explorer and standard plain mirror. The source of light has been a standard E. E. N. T. examination lamp.

Table 1. Distribution of continuous resident children examined in Grand Rapids and Muskegon, Mich., and in Aurora, Ill., according to age and year of examination

Age last birthday	1945 Aurora, Ill.	Basic ex- aminations 1944-45	1945	1946	1947	1948	1949	1950	1951
Grand Rapids, Mich.									
4	30	323	540	300	168	137	75	117	168
5	407	1,633	1,714	831	886	842	777	720	853
6	473	1,789	1,186	628	663	736	697	748	750
7	516	1,806	149	82	69	55	54	438	423
8	469	1,647	15	216	135	138	155	501	470
9	368	1,639		525	465	484	519	520	582
10	397	1,626		109	108	111	125	131	141
11	383	1,556		17	18	22	140	130	151
12	401	1,685	174	85	38	60	130	200	176
13	401	1,668	953	547	625	600	574	530	497
14	433	1,690	273	173	196	152	153	130	128
15	467	1,511	80	53	80	64	64	58	53
16	371	1,107	4	3	233	245	209	177	198
Muskegon, Mich.									
4		20		43	18	26	51	41	63
5		402		321	348	422	340	359	351
6		462		339	312	305	393	310	294
7		408		36	42	36	30	274	223
8		376		18	13	10	12	190	275
9		357		213	215	199	197	227	277
10		359		62	57	52	52	51	62
11		293		12	10	14	146	141	139
12		328		21	19	11	28	43	48
13		377		197	207	208	214	173	225
14		369		77	50	79	66	63	59
15		292		18	44	41	34	35	21
16		248		1	199	205	132	146	155

Bite-wing X-ray examinations were made of a representative sample of children examined by the different examiners to evaluate, in part, the "examiner error." The result of this evaluation will be the subject of another report. A complete oral examination was made and a residence history obtained, which, for the younger children, was verified by a questionnaire signed by parent or guardian. Only the principal dental findings will be considered here.

The examiner dictated his findings in code to recording scribes. The code used for recording dental conditions is similar to one described previously (12). It is designed to give a complete description of the health status of all teeth and each surface of individual teeth, both separately and collectively. A short "indoctrination" period was used to acquaint the examiners and scribes with the code and to establish consistency among examiners regarding the sub-

jective assessment features of diagnosis. Virtually all pupils of the school systems of the selected cities were examined, including nursery schools and junior college students where available.

Subsequent Annual Examinations

Following the original "prefluoridation" examinations, annual dental examinations have been made in Grand Rapids and Muskegon. These examinations are being conducted in the same manner as were the original ones. There have been changes in dental examiners with the exception of one officer who has participated in each series of examinations. Each new examiner has been calibrated against this one officer to standardize diagnostic criteria.

These annual examinations are made at the same time each year (October and November)

and are performed on selected samples of the school children. This annual study sample was selected after careful review of census data and consultation with city planning department officials. On the basis of available information, the 31 school districts of Grand Rapids were classified on a socioeconomic basis. From the 79 schools in these districts, 25 representative schools were selected, and the examiners were assigned schools on a basis of equal-sized samples of comparable population groups. In Muskegon, the annual examinations have been conducted in almost all schools, excluding only a few small schools on the periphery of the city where many students are from rural areas. The examiners work in the same schools each year. Each new examiner is assigned the schools which had previously been assigned to the examiner whom he replaced.

Selected age groups of children are examined within each of the schools. Selection is made on the basis of school grade or class; using all children present in a class or grade of a school. Choosing examinees by grade in this manner will, in some instances, not give well-distributed specific age groupings. For example, an eighth-

grade group will give a well-distributed 13-year-old age group, and will include the older 12-year-olds and younger 14-year-olds when specific age groups are based on age at last birthday. The number of grades included in the 1951 examinations give well-distributed age groupings through the 13-year-old groups.

Each child in a selected grade or class is examined regardless of his residence history. The examiner has no knowledge at the time of examination whether or not the individual examinee is a "continuous resident" of the city in which the examinations are being held.

The following table shows the grades, or selected class groups from these grades, which were included for each annual (fall) examination in Grand Rapids and Muskegon subsequent to the original or basic examinations:

Year	Grade or class
1945	Kindergarten, 1, 8
1946	Kindergarten, 1, 4, 8
1947	Kindergarten, 1, 4, 8, 11
1948	Kindergarten, 1, 4, 8, 11
1949	Kindergarten, 1, 4, 6, 8, 11
1950	Kindergarten, 1, 2, 3, 4, 6, 8, 11
1951	Kindergarten, 1, 2, 3, 4, 6, 8, 11

Table 2. Dental caries experience in deciduous and permanent teeth of continuous resident children of Aurora, Ill., as observed in the 1945-46 examination period

Age last birthday	Deciduous teeth		Permanent teeth				Percent of children with DMF teeth
	Number filled	Total def ¹	Decayed	Missing ²	Filled	Total DMF ³	
Number of teeth per child							
4	0.10	2.07	0	0	0	0	2.7
5	.25	2.79	.059	0	0	.059	15.2
6	.38	3.36	.263	.002	.015	.280	33.9
7	.44	3.51	.661	.009	.035	.705	44.8
8	.54	3.60	.917	.014	.111	1.042	55.2
9	.49	2.98	1.185	.063	.274	1.522	66.5
10	.27	2.28	1.426	.089	.505	2.020	72.3
11	.15	1.18	1.755	.227	.688	2.670	73.1
12	.05	.43	1.774	.219	.958	2.951	73.3
13	.01	.13	1.658	.236	1.195	3.089	78.3
14			1.750	.305	1.584	3.639	83.1
15			1.989	.501	2.047	4.537	85.4
16			1.941	.533	2.712	5.186	

¹ Decayed, extraction indicated, or filled deciduous teeth.

² Includes teeth listed as "remaining roots" and teeth destroyed beyond any possible repair.

³ Decayed, missing, or filled permanent teeth. Each tooth is counted only once. A tooth which shows a filled surface is considered a filled tooth regardless of whether or not it has additional carious areas.

Table 3. Dental caries findings, deciduous teeth, in Grand Rapids and Muskegon, Mich., school children, 4-13 years of age, according to year of examination

Age last birthday	Number of def ¹ deciduous teeth per child							
	Basic ex-aminations 1944-45	1945	1946	1947	1948	1949	1950	1951
Grand Rapids, Mich.								
4	4. 186	5. 398	3. 427	3. 190	3. 022	2. 747	2. 462	2. 131
5	5. 369	6. 151	5. 083	3. 893	4. 027	3. 273	2. 501	2. 273
6	6. 431	6. 979	5. 725	5. 379	4. 784	4. 590	3. 730	2. 977
7	6. 293	7. 658	6. 110	5. 841	5. 200	4. 833	4. 715	4. 031
8	5. 782	8. 000	5. 097	5. 074	4. 877	4. 748	4. 908	4. 123
9	4. 591	-----	4. 446	4. 110	4. 428	4. 410	4. 229	3. 856
10	2. 837	-----	2. 835	3. 157	3. 063	2. 856	2. 359	2. 426
11	1. 345	-----	2. 118	2. 778	1. 773	1. 193	1. 162	1. 351
12	. 473	. 276	. 129	. 105	. 250	. 354	. 245	. 295
13	. 176	. 130	. 139	. 136	. 170	. 103	. 147	. 117
Muskegon, Mich.								
4	5. 050	(²)	3. 442	4. 667	4. 385	4. 412	5. 317	4. 460
5	6. 820	-----	5. 860	5. 052	5. 552	5. 556	5. 649	5. 248
6	7. 167	-----	6. 239	6. 179	6. 056	5. 992	6. 019	5. 667
7	6. 663	-----	6. 833	5. 952	6. 917	6. 333	5. 825	5. 771
8	6. 061	-----	4. 833	3. 846	4. 800	6. 083	5. 063	5. 320
9	4. 885	-----	4. 315	4. 344	4. 714	4. 482	4. 088	4. 173
10	3. 084	-----	3. 145	3. 667	2. 788	2. 769	3. 490	2. 855
11	1. 328	-----	1. 667	2. 900	. 643	1. 212	1. 085	1. 460
12	. 422	-----	. 143	. 368	. 636	. 679	. 605	. 312
13	. 234	-----	. 289	. 174	. 106	. 112	. 127	. 147

¹ Decayed, extraction indicated, or filled deciduous teeth. A decayed and filled tooth is counted only as a filled tooth.

² The 1944-45 basic examinations in Muskegon were not done until late spring of 1945; therefore, no repeat examinations were made in the fall of 1945.

In addition to the routine dental examinations in these two cities, special studies, including bacteriological and chemical studies of the saliva, are being made on selected groups of children. The results of these studies will be reported at a later date.

Fluoridation

The addition of sodium fluoride (NaF) to the Grand Rapids water supply started in January 1945. Since that time, the people of this city have been ingesting a water with a fluoride content of 1 ppm F. Daily analyses show that this concentration has been maintained within a 0.2 ppm range (13). No significant mechanical difficulties of any consequence have been encountered. Also, in the course of 7 years of fluoridation, no established complaints of any

ill effects have been encountered from the numerous manufacturing and processing concerns, nor from the population involved.

The water supply at Muskegon remained unchanged until July 1951, when this city started adding fluorides to its water supply.

Results

Base-line data were obtained on the oral health status of 31,007 Grand Rapids residents aged 2-24 years, 8,304 Muskegon residents aged 4-25 years, and 8,811 Aurora, Ill., residents aged 4-20 years. The present report includes only the findings in regard to dental caries in "continuous resident" children aged 4-16 years. This selection excludes the results on children of these ages who have lived outside their respective communities for more than 3 months in

any one calendar year. Table 1 shows the number of continuous resident children of these ages examined each year and their distribution by age.

For purposes of comparison, the results of oral examinations of Aurora school children are shown in table 2. As mentioned previously, the results at Aurora represent the caries experience in children who have used water containing 1.2 ppm F throughout life. It is this same caries experience that one might expect to find in the teeth of Grand Rapids children after fluoridation has been in progress a comparable period of time in respect to the specific age group under comparison.

It should be noted that the dental examiners in this study obtained similar results to those

findings previously reported in the basic epidemiological studies for 12-14-year-old children of Aurora, Ill. (11).

The amount of dental caries experience observed at each examination in the deciduous and permanent teeth in both the study and control areas is shown in tables 3 and 4. There has been a reduction in the amount of dental caries observed in the Grand Rapids children subsequent to fluoridation of their water supply. For example, comparison of the 1951 and 1944-45 findings on permanent teeth shows this reduction to vary from 66.6 percent in the 6-year-old children to 18.1 percent in the 16-year-olds (table 4 and fig. 2). A similar comparison of results at Muskegon shows the percentage reduction to range from 1.5 percent in

Table 4. Dental caries findings, permanent teeth, in Grand Rapids and Muskegon, Mich., school children, 5-16 years of age, according to year of examination

Age last birthday	Number of DMF ¹ permanent teeth per child							
	Basic examinations 1944-45	1945	1946	1947	1948	1949	1950	1951
Grand Rapids, Mich.								
5	0.109	0.082	0.049	0.038	0.038	0.031	0.028	0.048
6	.775	.558	.234	.367	.262	.380	.261	.259
7	1.886	1.718	1.110	1.087	1.036	.759	1.034	.844
8	2.945	3.267	2.542	2.615	2.304	2.155	1.766	1.577
9	3.898	-----	2.981	3.116	2.671	2.478	2.383	2.040
10	4.921	-----	3.697	3.556	3.514	3.560	3.168	2.929
11	6.409	-----	4.235	3.556	4.318	4.686	4.362	3.669
12	8.073	9.529	7.624	7.026	8.317	7.015	7.100	5.886
13	9.734	10.759	8.920	8.469	8.338	8.111	7.206	6.600
14	10.945	11.901	9.410	9.500	9.414	8.895	8.546	8.211
15	12.482	12.675	11.264	11.938	10.609	11.797	10.121	8.906
16	13.499	13.000	9.333	12.472	13.502	11.833	11.350	11.061
Muskegon, Mich.								
5	.065	(²)	.044	.069	.062	.135	.086	.117
6	.811	-----	.481	.657	.790	.631	.748	.799
7	1.988	-----	1.331	1.048	2.194	1.433	2.011	1.879
8	2.810	-----	2.833	2.154	3.500	2.583	2.958	2.629
9	3.808	-----	3.291	3.535	3.578	3.883	3.894	3.516
10	4.906	-----	4.274	3.596	4.865	4.442	4.529	4.323
11	6.318	-----	4.250	4.700	4.714	5.932	5.667	5.338
12	8.655	-----	8.429	6.789	7.818	7.214	6.884	7.708
13	9.981	-----	9.015	9.227	10.524	9.523	9.578	9.364
14	11.995	-----	11.091	12.000	12.266	11.076	12.111	11.356
15	12.862	-----	11.167	12.886	12.659	10.324	10.943	12.381
16	14.068	-----	19.000	12.769	14.307	12.508	13.911	13.161

¹ Decayed, missing, or filled permanent teeth. A decayed and filled tooth is counted only as a filled tooth.

² The 1944-45 basic examinations in Muskegon were not done until the late spring of 1945; therefore, no repeat examinations were done in the fall of 1945.

6-year-olds to a high of 15.5 percent in the 11-year-olds. In Muskegon, the number of examinations was smaller, especially in the older age group. The 5-year-old group of 1951 is older by an average of 4 to 5 months than the same age group of 1944-45. Preschool children were examined in 1944-45, but in 1951 only children old enough for entrance to kindergarten were examined. It should be noted that the percentage reductions observed at Muskegon do not fit a consistent pattern as do those at Grand Rapids and may, in part, represent sampling error.

In establishing DMF rates, two portions of this rate are derived from observations based almost entirely on objective assessment, namely, the number of missing teeth and the number of filled teeth. Table 5 shows a comparison of the number of missing and filled permanent teeth

for the study and control areas. There has been a reduction in the average number of missing teeth observed in Grand Rapids children up to and including the 13-year-old age group. This situation did not prevail in Muskegon. The findings in regard to the average number of filled teeth in these two areas would not explain the reduction in missing teeth. There has been little change in the average number of filled teeth in Grand Rapids whereas in Muskegon this average shows some indication of having increased slightly in the younger age groups.

Discussion

The 1951 results in this report represent the findings of the seventh year of a study on the effect of fluoridation of public water supplies on dental caries prevalence. The results in

Table 5. Comparison of the number of filled or missing permanent teeth observed in Grand Rapids and Muskegon, Mich., children during the basic (1944-45) examination and the 1951 examination

Age last birthday	Filled permanent teeth							
	Grand Rapids, Mich.				Muskegon, Mich.			
	Number per child		Percent of total DMF		Number per child		Percent of total DMF	
	1944-45	1951	1944-45	1951	1944-45	1951	1944-45	1951
5	0.006	0.006	5.51	12.50	0	0.011	0	9.40
6	.072	.068	9.29	26.26	.063	.109	7.77	13.64
7	.338	.317	17.92	37.56	.312	.404	15.69	21.50
8	.822	.834	27.91	52.89	.719	.927	25.59	35.26
9	1.395	1.220	35.79	59.80	1.518	1.690	39.86	48.07
10	1.899	1.270	38.59	43.36	2.100	1.613	42.80	37.31
11	2.559	2.437	39.93	66.42	2.497	2.237	39.52	41.91
12	3.480	4.239	43.11	72.02	3.930	3.000	45.41	38.92
13	4.444	4.525	45.65	68.56	4.603	4.907	46.12	52.40
14	5.454	4.602	49.83	56.05	5.637	3.797	46.99	33.44
15	6.738	5.604	53.98	62.92	6.773	5.476	52.66	44.23
16	8.406	8.263	62.27	74.70	8.426	8.916	59.90	67.75
	Missing permanent teeth							
5	0.001	0			0	0		
6	.001	0			.004	0		
7	.017	0			.017	.013		
8	.044	.013			.037	.044		
9	.150	.046			.160	.101		
10	.281	.163			.241	.339		
11	.478	.179			.407	.468		
12	.645	.460			.741	.854		
13	.836	.366			.937	.929		
14	1.045	1.195			1.149	1.085		
15	1.239	.849			1.240	1.857		
16	1.501	1.197			1.500	1.574		

Grand Rapids for 1951 represent findings after 6½ years of exposure to a fluoride water environment. The tabular data indicate a definite reduction in age specific caries rates in Grand Rapids children. As shown in figures 1 and 2 the observed caries rates for Grand Rapids have changed over the past 6 to 7 years and in the younger age groups are approaching the findings on continuous resident children of Aurora, Ill., in 1945-46.

It is of special interest to note the increment in dental caries between ages 6 and 9 years. In Grand Rapids for this age period in the basic examinations, this increment was 3.123 DMF teeth per child as compared to 1.781 DMF teeth per child in the 1951 examinations. For Muskegon children, the basic examination results indicate an incremental increase between the years of 6 to 9 of 2.997 DMF teeth as compared to 2.717 as observed in 1951. Thus, the increment of dental caries over this 3-year-age period has decreased in Grand Rapids by 1.34 DMF teeth while at Muskegon the decrease is only 0.28 DMF teeth.

Attention is called to the fact that DMF rates in this age group (6-9 years) reflect mainly the caries rates in first permanent molars. In other words, the results to date on Grand Rapids children indicate that their first permanent molar teeth are decaying at a rate which is only 57 percent of the 1944-45, or prefluoridation,

Figure 1. Comparison of dental caries experience in deciduous teeth of continuous resident school children in Grand Rapids, Mich., and Aurora, Ill.

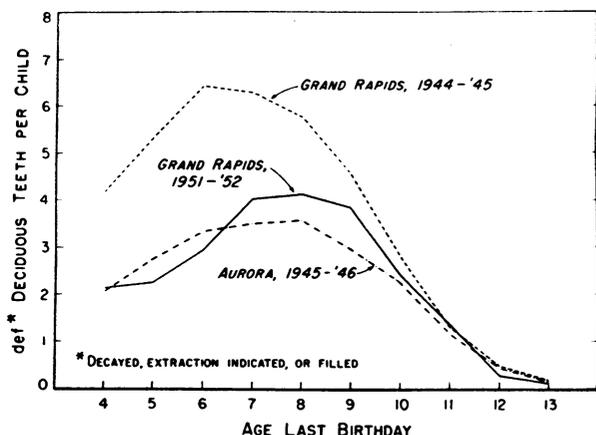
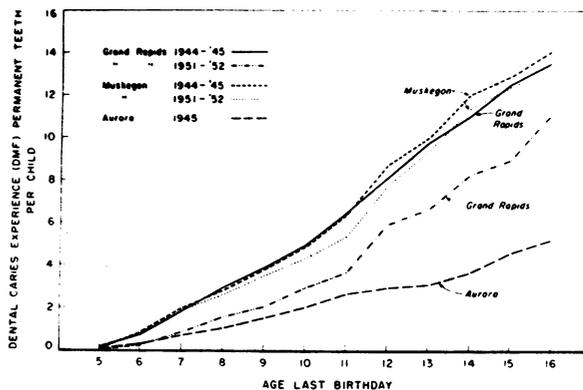


Figure 2. Comparison of dental caries experience in permanent teeth of continuous resident school children in Grand Rapids and Muskegon, Mich., and Aurora, Ill.



rate. Also, considering that only the 6-year-old and part of the 7-year-old children were born into a fluoride environment, this result is consistent with the findings for Aurora children.

It should be noted that the only known major change affecting the environment of these two groups of children over the period of study has been the fluoridation of the Grand Rapids water supply. There have been no concerted efforts to inaugurate any special caries control programs, such as topical fluoride programs, in either city since the study started. From an epidemiological standpoint the results of this study, together with those of other comparable studies, permit the conclusion that adjusting the fluoride content of public water supplies will result in a reduction of the incidence of dental caries in school children.

Summary

The methodology and results after 7 years of the Grand Rapids-Muskegon study have been described. The 1951 results on continuous resident children after 6½ years of fluoridation of the Grand Rapids water supply indicate:

1. There has been a reduction in dental caries rates in permanent teeth of Grand Rapids children ranging from 66.6 percent in 6-year-old children to 18.1 percent in the 16-year age group. Similar results have been obtained regarding the deciduous teeth.
2. Similar reductions have not been observed in Muskegon where the water supply remained

“fluoride-free” (<0.2 ppm F) until the last 3 months of this study period.

3. This change in dental caries rates at Grand Rapids was also reflected in observations based on objective assessment, that is, a reduction in the number of missing teeth.

4. A comparison of the 1951 caries rates in Grand Rapids with those of Aurora, Ill., shows that insofar as can be determined to date the use of a fluoridated water gives the same beneficial effects as does the use of a natural fluoride water of similar concentration.

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